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TITLE: Water Treatment for Atomic Power Stations

/Obrabotka vody v atomnykh energeticheskikh ustanovkakh/

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Selection of a desalting method depends on the properties of the source water and on the requirements imposed on the quality of the desalted water. The water with the lowest salinity is the highly pure water used in atomic power stations. However, radiolysis, dissociation, and corrosion constantly add impurities to this water, with the result that it is always being purified to maintain quality, primarily by the use of what is the most effective method, that of ion exchange.

Let us consider the arrangement used to treat the water in one of the transportable American atomic power stations (fig. 11), one which is quite similar to that used to treat water in the large atomic power stations [14].

The reactor core (enriched uranium) is located in a stainless steel container and is cooled by water under a pressure of 84 ata, flowing at 910m^3/hr. The water is heated to 232°C and gives up its heat to the water in the secondary circuit as it flows through the steam-generator, which contains U-shaped,
p.43 vertical tubes, cooling to 220°C in the process. The steam-generator produces steam at a pressure of 14 ata and a temperature of 194°C.

Table 2 lists water conditions in various of the reactor assemblies. The primary circuit contains all the water and equipment in contact with the core, while the secondary circuit includes the water and equipment in the steam-generating cycle.

There are many reasons why water of uncommonly high purity is required for the primary circuit.

Contaminants, particularly in the form of admixtures of sodium, cobalt, and manganese in the water can become radioactive. When these settle in the zone serviced by the technical personnel they create an irradiation hazard. Moreover, mechanical admixtures in the water can result in reduced clearances and, as a result, to disruption of normal operation of machinery.

Surface deposits have been known to cause disruptions in the functioning of the control rods in a water-moderated water-cooled reactor. Possible as well is an upset in the heat exchange and the normal flow of water between the fuel elements because the thickness of the water layer between two adjacent elements has been upset.

Continuous purification of some of the water in the reactor provides primary circuit water salinity in the range up to 2 mg/liter. The water being purified (purged) is withdrawn from the primary circuit at 220°C and

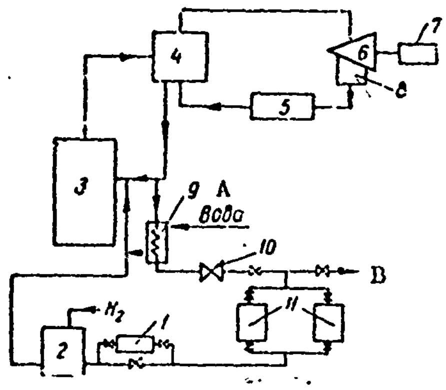

Figure 11. Simplified schematic of a transportable atomic powered electric station. 1 - filter; 2 - primary water tank; 3 - reactor; 4 - steam generator; 5 - feed water heater; 6 - turbine; 7 - generator; 8 - condenser; 9 - heat exchanger-cooler; 10 - throttle valve; 11 - FSD (combination filter). A - water; B - to drain.

84 ata, and since most of the ionites are broken down at temperatures higher than 50°C, this water is cooled in the heat exchanger to 49°C and its pressure on the discharge side of the throttle valve is reduced to 7 ata.

The water being purged then flows through one of the two combination (FSD) ionite filters, which removes most of the impurities. The water then flows into the stainless steel tank (with a volume of about 20 m^3) and is returned to the primary circuit. Just how much water is purged depends on the corrosion rate, the magnitude of the primary circuit surface, system

p.44 volume, and the efficiency of the ionite filters. The quantity of water purged in stainless steel reactors will be greater during the initial period of operation of the reactor, when corrosion intensity is higher. After corrosion has stabilized the quantity will vary, depending on how well the ionite filters functions.

Corrosion rates for reactors will, on the average, run about 0.05 $mg/cm^2/month$. The amount of water purged can be computed using the formula

$$G = xF/720(S_1 - S_m) \text{ , liters/hour ,}$$

where

G is the quantity of water being purged, liters/hour;

x is the corrosion rate, mg/cm^2/month;

F is the surface in contact with the water, cm^2;

S_1 is salinity of water in primary circuit, mg/liter;

S_m is salinity of makeup water for the primary circuit, mg/liter.

Table 2. Purpose of the water in various of the assemblies in a water-moderated water-cooled atomic reactor [49,a]

Type of water (system)	Purpose
Water supply	Feed to distiller making distillate
Distilled water	Secondary circuit makeup; primary circuit ionite filter makeup; air-tight pump cooling; cooling shielding layer water
Chemically treated makeup water for secondary circuit	Steam generator feed
Desalted water containing excessive hydrogen	Primary circuit makeup water
Distilled water in which fuel elements are stored	Storage of spent fuel
River (sea) water	Cooling condensers, coolers, etc.
Water purged from the primary circuit	Purification of purged water to required degree and reuse
Water for sealing	Sealing for control rod actuators.

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This reactor has a primary circuit surface of some 400 m^2, and the water salinity can be taken as about 2 mg/liter.

Combination ionite filters are used, and when exhausted should be regenerated. However, in view of the complexity and undesirability of this operation because of the high degree of radioactivity of large volumes of substances being reprocessed and of rinse water, it is recommended that ionite filters and their containers be replaced.

The ionite filters usually used are some 305 mm in diameter, 915 mm high, and have an ionite charge with a volume of 0.057 m^3. Stainless steel is used for the covers, filter housings, pipelines, and fittings. Inlet and outlet piping at the upper part of the container is fitted with quick release fittings. Corrosion products in a reactor of this type are in the main insoluble oxides of iron, nickel, chromium, as well as manganese and cobalt compounds.

Service life of the ionite materials can be prolonged if most of the

corrosion products are removed by preliminary filtering. The mechanical filters in use at the present time become contaminated in short order and require frequent washing out. This wash water then becomes saturated with radioactive isotopes, and it is very difficult to render the water harmless. Hence, ionite filters are used for mechanical filtering, as well as for desalting. Attempts have been made to provide for the use of heat-resistant ionites which have a high absorption capacity.

Combination ionite filters are filled with a mixture of H-cationite and heavy-based OH-anionite.

Oxygen is kept as low as possible to prevent oxygen corrosion. Oxygen also puts in an appearance as a result of the radiolysis of water, so, in order to prevent this from happening in operation, hydrogen, the concentration of which should be 15 to 45 cm^3/liter, is introduced into the makeup water tank. A batcher pump adds hydrazine to bind the oxygen in the water in the primary circuit when the system is being filled and started up, that is, when there is no radiation.

A micrometallic, stainless steel filter, which is used to capture the ionite grains, or other solid particles larger than 7 microns, is installed

p.46 after the ionite filter. The system has a by-pass so it can function without the filter during replacement. The primary circuit makeup water pumps supply the water for sealing the control rods. An excess of hydrogen is maintained here as well in order to prevent air suction. The makeup water needed for the primary circuit is supplied as deaerated condensate which has first been desalted in the ionite filters, the combination type.

The water is automatically purged from the primary circuit into an underground tank made of carbon steel should the fuel jacket be damaged and fission products enter the water.

The requirements imposed on the water in the secondary circuit in nuclear power plants are more stringent than are those for conventional steam-powered plants. Specifically, the possibility of corrosion destruction of the circuit material by the impurities present requires careful monitoring of the impurities contained in the water. The chloride concentrations in the water in the reactor under consideration must not be in excess of 0.5 mg/liter, for example. In the case of rated purging (1%), this limits the concentration of chlorides in the feed water to 0.005 mg/liter.

There is a certain amount of water which must be added to the secondary circuit during operation of the reactor in order to compensate for that purged,

and to make up the water lost by leakage. The makeup water is obtained from a special distiller which makes 1 ton of water per hour. The distillate is also used for the ionite filters in the primary circuit, for cooling the cirulator pumps in the primary circuit, and for cooling the protective layer of water.

Table 3. Values for indices being monitored for the water in the primary and secondary circuits.

Substance being monitored	Circuit	Quantity, mg/l
Chlorides	I, II	0 - 1.0
Oxygen	I, II	0 - 1.0
Hydrogen	I	0 - 30
Hydrazine	I, II	0 - 0.5
Iron	I, II	0 - 1.0
Cobalt	I	0 - 0.1
Nickel	I	0 -
Manganese	I	0 - 0.[illegible]
Chromium	I	0 - 0.5
Phosphates	II	0 - 10
Sulphite	II	0 - 10
OH-ions	II	0 - 10
Ammonia	I	0 - 0.5

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The manner in which the quality of the water in the secondary circuit is regulated is approximately the same as that used for the purpose in conventional steam-powered installations. Ejectors ensure a residual oxygen content in the water in the turbine condenser (from the deaerator tank) of less than 0.03 mg/liter. The residual oxygen is bound by the hydrazine.

Table 3 lists the conventional values for the water indices being monitored in both circuits. It should be borne in mind that a particularly broad selection and analysis of samples taken from both primary and secondary circuits is made during the start-up and sub-critical periods of installation operation.

Ionite water purification more effectively satisfies the requirements imposed on water regimes for atomic power stations. There are other atomic power stations (Shippingport) in which the ionite filters work under full operating pressure.